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Methodology for calculation and design of earthquake-resistant vibroisolated turbine foundations

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Abstract. The object of research in the article is the vibroisolated foundation of a high-power turbine unit (1000 MW). World energy is developing rapidly today and there is a need to build energy facilities in areas of high seismicity. The acute question is the lack of a comprehensive methodology for calculating and designing earthquake-resistant foundations of turbine units. The article proposes a general procedure of actions aimed at increasing the seismic resistance of the foundations of turbine units. Implementation of the proposed methodology was carried out on a specific example of a vibroisolated foundation: the dependences of seismic accelerations and displacements were obtained for different variants of seismic isolation. Application of the above technique allows to reduce seismic acceleration on capacitors by more than 2 times, seismic movements of capacitors by more than 3 times.

1. Introduction

In the current conditions of the development of world industry and nuclear energy, the construction of industrial and energy facilities in areas with high seismic activity as part of the development of the corresponding capacities of individual regions and states is of particular importance. This circumstance is due to the need to ensure high reliability of the operation of the relevant construction projects, including through the implementation of measures to reduce the negative physical effects on the structural elements of construction projects, due to both internal and external factors. Moreover, among external factors, a special form of natural influences – seismic – is of particular importance. This circumstance is associated primarily with the nature of the impact of these loads on the structural elements of construction objects, as well as the difficulty in predicting the scale and time intervals for the manifestation of the corresponding natural phenomena, as well as the severity of the possible consequences. The complexity of developing appropriate structural, organizational and technological solutions is determined not only by the need to ensure rigidity and strength of the corresponding structural elements of construction objects, but also by the importance of taking into account the characteristics of soils located in the construction location. Based on the above-mentioned, a conclusion was drawn on the feasibility of conducting a study, the purpose of which is to develop a procedure for substantiating the characteristics of structural solutions in the field of protecting structural elements of industrial and energy construction from seismic loads. To achieve this goal, the following research objectives were formulated:

1. Review and analysis of scientific work on the research topic.
2. Development of a procedure for substantiating structural solutions in the field of protecting structural elements of industrial and energy construction from seismic loads.
3. Implementation of the developed procedure on a practical example.

At the initial stage of the study, a review and analysis of literary sources related to the research topic was carried out. Despite the large number of scientific works in the field of designing structural elements as

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part of industrial and energy construction, the number of methodological developments and tools directly related to solving the problems of substantiating the characteristics of the above elements from the point of view of protection against seismic loads is relatively small. This circumstance is mainly due to the need to take into account the dynamic factor in the formulation and solution of the corresponding design problems, which, in turn, determines the high complexity of the calculations, the effectiveness of which is directly determined by the level of development of information and computer technologies. That is why the first applied research in the field of protection of structural elements from seismic loads began only in the second half of the XX century. In particular, in the Soviet Union, the first research in the field of seismic protection of building structure elements was carried out at the Central Scientific and Research Institute of Civil Engineering under the direction of Ya.M. Eisenberg [1–2]. The results of these studies were the basis for scientific and methodological developments and tools in the corresponding field of research. In the late 70^{s} of the 20^{th} century, the first mass construction of buildings and structures with seismic isolation systems in the form of turn-on and turn-off connections during the construction of the Baikal–Amur Mainline route began.

The city of railroad workers (82 buildings) was built up with seismically insulated buildings based on large-panel series 122. This was the first experience in the world in applying such a seismic protection system in residential buildings [1]. These circumstances, in particular, determined Russia's advancement to the leading places in the world in the number of built structures with various seismic isolation systems (more than 600 objects).

The appearance of new and improvement of already created scientific developments in the field of seismic isolation of building structures is inextricably linked with the development of dynamic calculations (in particular, seismic), the development of various methods of mathematical modeling in the calculation of structures, the improvement of construction-base interaction theories, soil calculation methods, and much more.

Among domestic and world scientists in the direction of seismic design calculations, it should be noted such scientists as Y.M. Eisenberg, A.N. Birbraer, I.I. Goldenblat, M.F. Barshtein, B.G. Koronev, I.M. Rabinovich, I.A. Konstantinov, N. Newmark, E. Rosenblatt, S.L. Timoshenko, S.T. Shulman.

General issues of designing structural elements as part of industrial and energy construction in areas with high seismic activity are covered in works of Hiraki (2014), Chen (2014), Kumar, Whittaker and Constantinou (2015) [3–7].

A detailed description of the relevant design solutions in the field of protecting elements of building structures as part of industrial and energy construction is presented in works of Medel-Vera (2015), Sayed (2015), Firoozabad (2015), Zhou, Wong and Mahin (2016), Kostarev, Petrenko and Vasilyev (2007) Sargsyan (2013), Birbraer (2017) Turilov (2017), Tyapin (2019) [8–24]. These decisions include the following:

- the use of seismic isolation systems to reduce the lower natural frequencies of structural elements of buildings and structures, as well as related technological equipment;
- the use of damping devices to increase the dissipation of kinetic energy that appears in the structural elements of the building under seismic impact;
- use of a non-standard approach in the field of Soil Structure Interaction.

It is important to note that the implementation of the above design solutions in the general case is characterized by rather high labor and money costs, but it does not always provide a high level of reliability of the operation of the construction site in conditions of increased seismic activity for the following main reasons:

- the difficulty of conducting full-scale tests of fully seismically insulated heavy buildings, and, as a result, the difficulty of verifying design methods;
- the difficulty of correct accounting in dynamic design models of construction objects for the stiffness and attenuation of individual elements of building structures, as well as large-sized technological equipment.
- unreasonable increase in damping characteristics in the ground.

To increase the efficiency of constructive solutions and reduce the complexity of the process of their development in the works of Belash (2019), Muravyeva and Vatin (2014), Egarmin (2015), Dražić and Vatin (2016) Rutman and Ostrovskaya (2018) [25–30] offers various options for dynamic calculation methods, including taking into account damping.

However, the relevant works describe only the general principles of accounting for seismic effects without taking into account the features of structural elements in industrial and energy construction facilities (these features are determined, in particular, by the purpose of the facility, the appropriate space-planning solution, the applied technological equipment, etc.). At the same time, the specified works do not provide specific methods for substantiating the characteristics of structural solutions in the field of protecting structural elements in construction objects from seismic influences.

Thus, according to the results of the review and comparative analysis of literary sources on the research topic, the following conclusions were made:

– a relatively small proportion of the number of works devoted to the development and analysis of design solutions in the field of protecting industrial and energy construction objects from seismic loads in the total number of works related to the design of industrial and energy construction objects;
– lack of tools providing substantiation of the characteristics of structural solutions in the field of protection of structural elements in industrial and energy construction objects from seismic effects.

The above conclusions once again confirmed the relevance of the study and were the basis for the implementation of its subsequent stages – the development of a procedure for substantiating the characteristics of structural solutions, a more detailed description of which is presented in the following sections of the work.

The object of research is the vibroisolated foundations of high-power turbine units (1000 MW). The aim of the study is to determine and formulate a comprehensive methodology for calculating and designing earthquake-resistant vibroisolated foundations of turbine units. During the study, the following main tasks were posed and solved:

1. Formulation of methods for calculating and designing earthquake-resistant vibroisolated foundations of turbine units;

2. Implementation of the proposed methodology on a specific example, by conducting computational experiments;

3. Analysis of increasing the seismic resistance of the vibroisolated foundation of the turbine unit when applying the proposed methodology.

2. Methods

As part of the next phase of the study, a procedure was proposed for substantiating the characteristics of structural solutions for protecting structural elements in industrial and energy construction from seismic effects. The structure of the developed procedure is presented in the form of a flowchart in Fig. 1 and has the following main features:

1. The general process of solving the problem of substantiating the characteristics of structural solutions to protect the structural elements of building objects from seismic influences includes the following key steps:

– construction of a comprehensive model containing adjustable and unregulated parameters of the studied structural elements, as well as design characteristics for evaluating alternative constructive solutions;
– description of alternative constructive solutions by forming appropriate combinations of adjustable parameter values;
– creation of a calculation model (in a pre-selected software environment) based on the above calculation;
– implementation of computational experiments on the developed computational model in accordance with pre-formed alternative design options;
– the choice of the most preferred design solution based on the results obtained from the implementation of computational experiments.

2. The basic principles for constructing a comprehensive model are the following:

– as unregulated are assigned parameters that describe the construction object and its structural elements, which, when perceived by seismic loads, do not cause a decrease in the reliability indicators of the facility;
– as adjustable parameters are assigned that describe the structural elements of the construction object or appropriate technological equipment, the perception of which seismic loads significantly affects the reliability indicators of the facility;
– as design characteristics for evaluating the effectiveness (preference) of structural solutions for protecting structural elements of an object from seismic influences, particular indicators are assigned that are determined by analyzing the dependences of seismic accelerations and displacements in the corresponding supporting components of structural elements on the time factor or frequency characteristics of external influence (for example, peak seismic acceleration, zero period acceleration (ZPA) and deformation of support components).

3. General requirements for software in the field of modeling of computational models, which can be used to solve the problem, are the following:

- the possibility of implementing the finite element method of the spatial configuration;
- the ability to implement dynamic calculations by directly integrating the equations of motion;
- the ability to account for concentrated dampers in the design scheme;
- the ability to numerically and graphically display selected design characteristics.

4. The construction of the calculation model is based on the corresponding complex model according to the following basic principles:

- unregulated and adjustable input parameters of the model are formed in accordance with unregulated and adjustable (according to the design options) parameters of the structural elements of the object in question, taking into account the structural features of the models within the selected software environment;
- model output parameters are formed on the basis of design characteristics for evaluating the effectiveness (preference) of structural solutions and, in the general case, describe the dependence of the seismic resistance characteristics of the considered structural elements or technological equipment on the time factor or on the frequency characteristics of external influence.

5. The choice of the most preferable constructive solution based on the results of the implementation of computational experiments in the selected software environment is advisable to carry out by the method of linear convolution. The corresponding mathematical expressions have the form:

$$i^*: \ Q_{i^*} = \max_i \{Q_i\}, \tag{1}$$

$$Q_i = \sum_{j=1}^{n} \alpha_j \cdot \frac{q_{ij} - q_j^{\text{worst}}}{q_j^{\text{best}} - q_j^{\text{worst}}}; \tag{2}$$

where i^* is index of the most preferred design solution in the field of protecting structural elements of an object from seismic effects;

Q_i is the value of a generalized indicator of the effectiveness i ($i = 1, 2, ..., m$, where m is total number of options) of a design solution option;

n is total number of design characteristics for evaluating the effectiveness (preference) of constructive solutions;

α_j is coefficient of significance of accounting for the calculated characteristic j ($j = 1, 2, ..., n$) to evaluate the effectiveness (preference) of constructive solutions; coefficients $\{\alpha_j\}$ must satisfy the conditions:

$$\begin{cases} \alpha_j \geq 0, \ j = 1, 2, ..., n; \\ \sum\limits_{j=1}^{n} \alpha_j = 1. \end{cases} \tag{3}$$

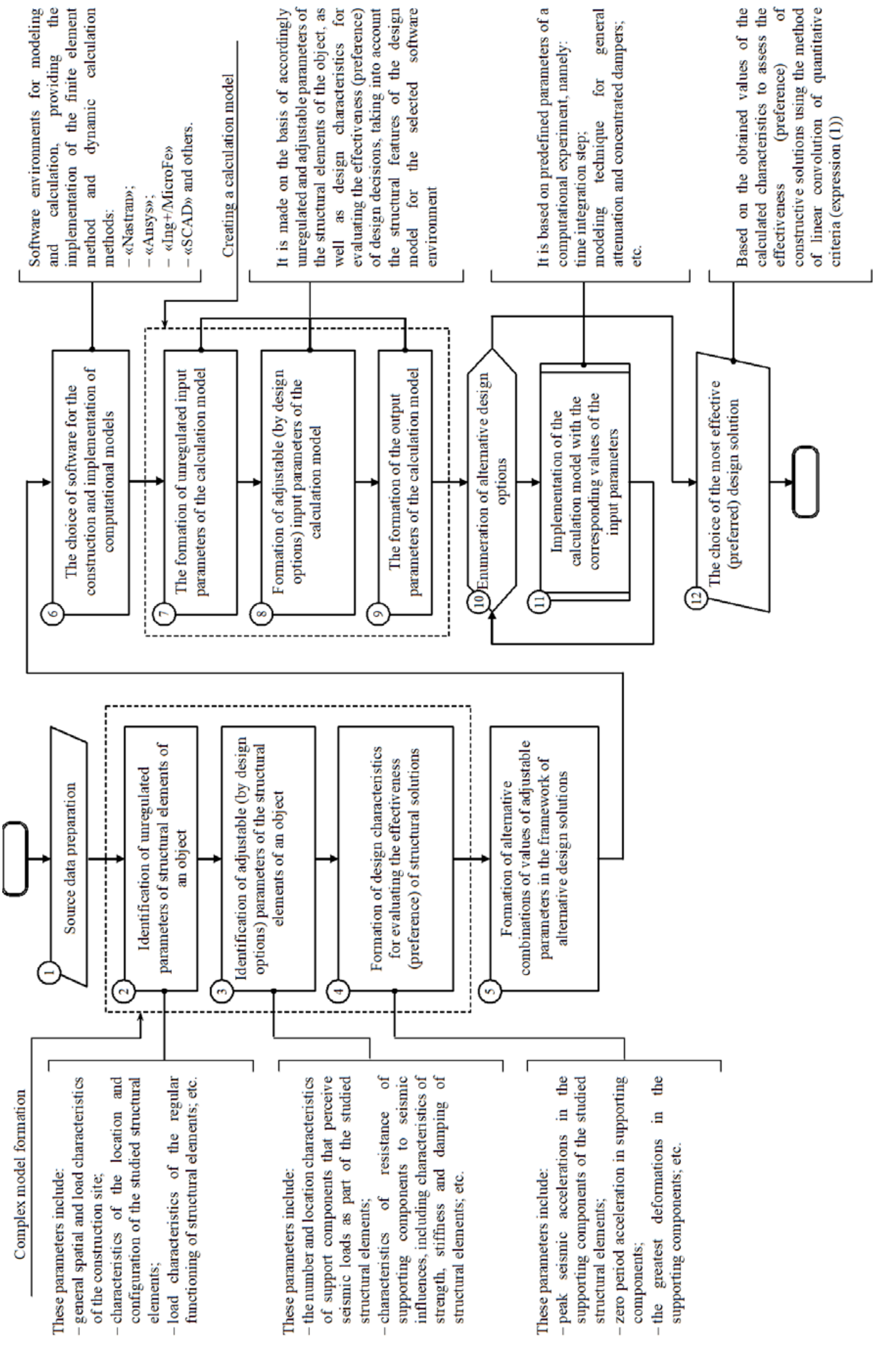


Figure 1. A flowchart describing the structure of the proposed procedure.

q_{ij} is value of design characteristic j ($j=1,2,...,n$) to evaluate the effectiveness (preference) in relation i ($i=1,2,...,m$) to the design solution;

q_j^{best}, q_j^{worst} are respectively, the most and least preferred value of the design characteristic j ($j=1,2,...,n$) to evaluate the effectiveness (preference) of constructive solutions;

$$q_j^{\text{best}} = \begin{cases} \max\limits_i \{q_{ij}\}, & \text{if the growth of the characteristic determines increased preference;} \\ \min\limits_i \{q_{ij}\}, & \text{otherwise;} \end{cases} \quad (4)$$

$$q_j^{\text{worst}} = \begin{cases} \min\limits_i \{q_{ij}\}, & \text{if the growth of the characteristic determines increased preference;} \\ \max\limits_i \{q_{ij}\}, & \text{otherwise.} \end{cases} \quad (5)$$

A detailed description of the implementation process of the proposed procedures on a practical example of use in the next section of the work.

3. Results and Discussion

At the next stage of the study, the proposed procedure was implemented using a practical example – substantiating the characteristics of a structural solution for technological equipment – a high-speed turbine unit – as a structural element of an energy facility – a turbine building with a monolithic reinforced concrete frame – as part of a power plant. At the initial stage of solving the problem, the initial data were collected and systematized (block 1 of the scheme in Fig. 1). The generated schematic description of the structural

At further stages of solving the problem, an integrated model for solving the problem was created. A description of the main adjustable and unregulated parameters of the complex model (blocks 2–4 of the circuit shown in Fig. 2) is presented in Table 1.

Table 1. Structural elements of the developed calculation model.

№ in order.	Name	UoM.	Value / Category
1	**Unregulated parameters**		
1.1	Turbine building length	m	100
1.2	Turbine building width	m	60
1.3	Turbine building height	m	35
1.4	The altitude mark of the placement of the foundation of the turbine unit	m	15
1.5	Frame material	-	concrete B25
1.6	The mass of the turbine building with equipment, more	t	115000
1.7	Mass of the isolated foundation of the turbine unit, more	t	9000
1.8	Seismic impact area	-	base plate bottom surface *
1.9	Locations of points (at the installation marks of the turbine unit and condensers) for calculating the design characteristics	-	see Fig. 2, b and 2, c
1.10	Number of marks for calculating design characteristics:		
1.10.1	at the installation mark of the turbine unit	un.	12
1.10.2	at the installation mark of capacitors	un.	8
1.11	Total attenuation (damping)	%	4
1.12	Peak acceleration on the free surface of the soil in the horizontal direction	m/s^2	1.7

№ in order.	Name	UoM.	Value / Category
2	**Adjustable parameters (by design options)**		
2.1	The number of insulating elements at the installation marks of the turbine unit and condensers	un.	value
2.2	Type of insulating elements at the installation marks of the turbine unit and condensers	-	value
3	**Design characteristics for evaluating the effectiveness of structural solutions**		
3.1	Averaged spectrum of the response of seismic accelerations at the installation marks of the turbine unit and condensers for axial, transverse and vertical directions	m/s^2 from *f* (Hz)	dependence
3.2	Peak seismic acceleration at the installation marks of the turbine unit and condensers for axial, transverse and vertical directions	m/s^2	value
3.3	Acceleration of the zero period at the installation marks of the turbine unit and condensers for axial, transverse and vertical directions	m/s^2	value
3.4	Normalized greatest strains in insulators at the installation marks of the turbine unit and condensers for axial, transverse and vertical directions	Mm	value

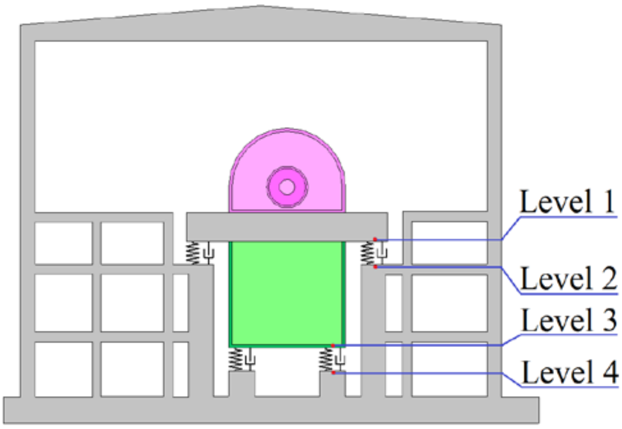
Note: * it was assumed that the lower foundation slab is absolutely rigid, therefore, the influence of soil properties in the calculation was not taken into account.

As adjustable (by design options) parameters, the characteristics of vibration-insulating systems were considered in terms of the number and type of insulating elements in two groups placed in the support components of the turbine unit (Levels 1-2 in Fig. 2, a) and the condenser (Levels 3-4 on Fig. 2, a), respectively.

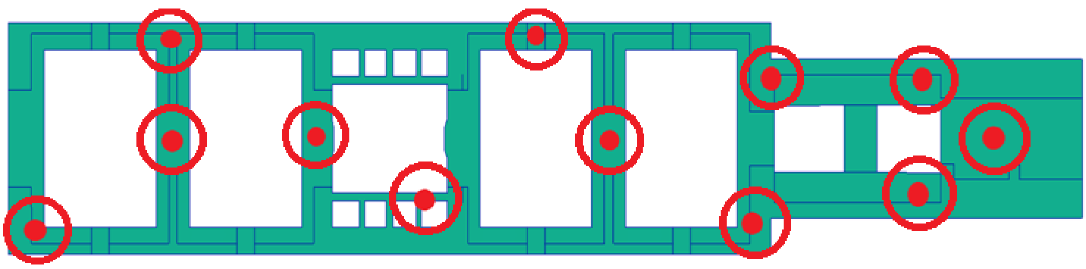
At the next stage of solving the problem, alternative constructive solutions were developed for vibration isolation of the technological equipment under consideration (block 5 of the diagram in Fig. 1). In total, five different constructive solutions were developed; their detailed description is presented in Table 2.

As part of the next stage of the study, the choice was made of software for creating a calculation model based on a previously developed integrated model (block 6 of the scheme in Fig. 1). As the specified software, the Nastran program was chosen for performing dynamic calculations, as it provides the optimal ratio of the complexity of creating and implementing the calculation model and the adequacy of the results obtained in the implementation of the corresponding computational experiments.

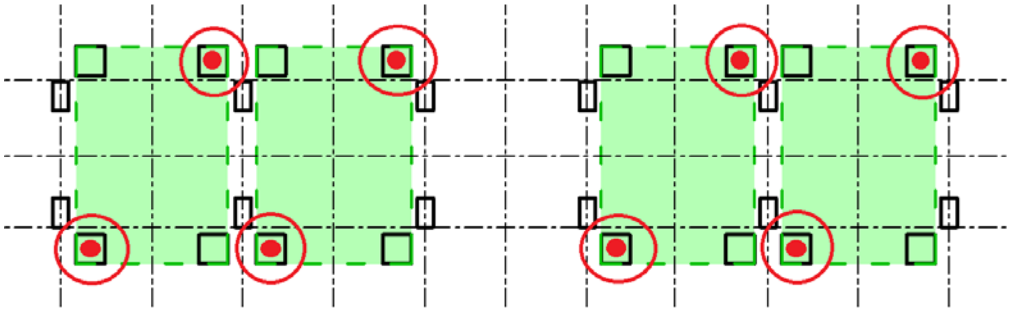
Further, using the selected program, a calculation model of the object of study was created. The basis of this development was the finite element model, a graphical description of which is presented in Fig. 3.



a)



b)



c)

Figure 2. Description of the structural element under consideration – the foundation of the turbine unit – as part of the construction project: a) – generalized scheme (cross section); b) –points for calculating the output characteristics of the calculation model at the turbine unit mark (levels 1-2); c) – points for calculating the output characteristics of the calculation model on capacitors (levels 3-4).

The structural elements of this model in terms of adjustable and unregulated input parameters, as well as output parameters (blocks 7–9 of the circuit in Fig. 1) correspond to the corresponding elements of the complex model. The main principles of creating a calculation model were the following:

- characteristics of the finite element mesh – the number of nodes and the configuration of their interconnections is determined by the spatial characteristics of the investigated construction object and its structural elements;
- environmental impact characteristics – seismic effects – are determined by quantitative characteristics – peak acceleration on the free surface of the soil, frequency composition of the synthesized accelerogram;
- the averaged response spectra of seismic accelerations at the installation marks of the turbine unit and condensers for axial, transverse and vertical directions (paragraph 3.1 of Table 1) were obtained as the average of all spectra at this mark, with peak expansion by 15 %. No additional peak reduction was performed.

At the next stage of solving the problem, computational experiments were performed, each of which corresponded to a separate version of the design solution for protecting technological equipment (as a structural element in the construction site) from seismic loads (blocks 10, 11 of the circuit in Fig. 1). The general parameters for the implementation of computational experiments on the model developed by Nastran are presented in Table 3. A graphic description of the output parameters of the model calculated as part of the above experiments is presented in Fig. 4.

Table 2. Description of design options for protecting process equipment from seismic loads.

Design option number	Design element name	Designation in Fig. 2 a	The number of insulating elements *			
			Spring insulators	Rigid spring insulators **	Spring damper insulators	Dampers
1	Capacitor supports	levels 1-2	4×4			
	Turbine unit foundation supports	levels 3-4	94			
2***	Capacitor supports	levels 1-2	4×4			
	Turbine unit foundation supports	levels 3-4	62		32	
3	Capacitor supports	levels 1-2	4×4			4×4
	Turbine unit foundation supports	levels 3-4	62		32	
4	Capacitor supports	levels 1-2		4×4		4×4
	Turbine unit foundation supports	levels 3-4	62		32	
5	Capacitor supports	levels 1-2		4×4		
	Turbine unit foundation supports	levels 3-4	62		32	

Note: * the maximum possible number of insulating elements is limited by a fixed size of the supporting surface area, layout, as well as maintenance requirements;
** horizontal stiffness of spring insulators doubled compared to standard;
*** this option is a standard version of the vibration-insulated foundation of a turbine unit, which differs from that used in areas with low seismic activity only by an increased number of damping elements.

Table 3. General parameters for the implementation of computational experiments on a model developed in the "Nastran" program.

№ in order.	Name	UoM.	Value
1	Dynamic calculation method	-	direct integration method of equations of motion
2	Integration step in the calculation of spectra	s	0.002
3	Integration step for calculating displacements	s	0.005
4	General attenuation modeling technique	-	Rayleigh technique

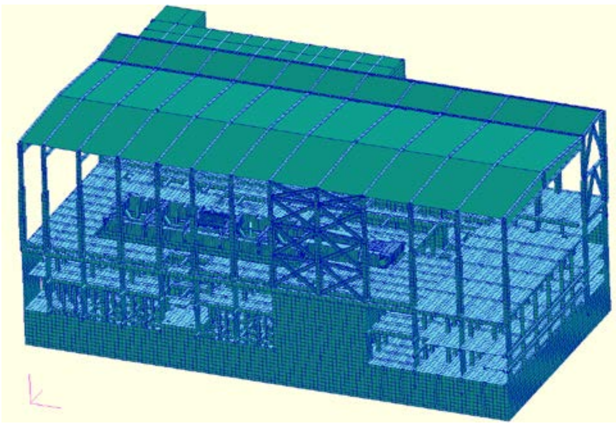
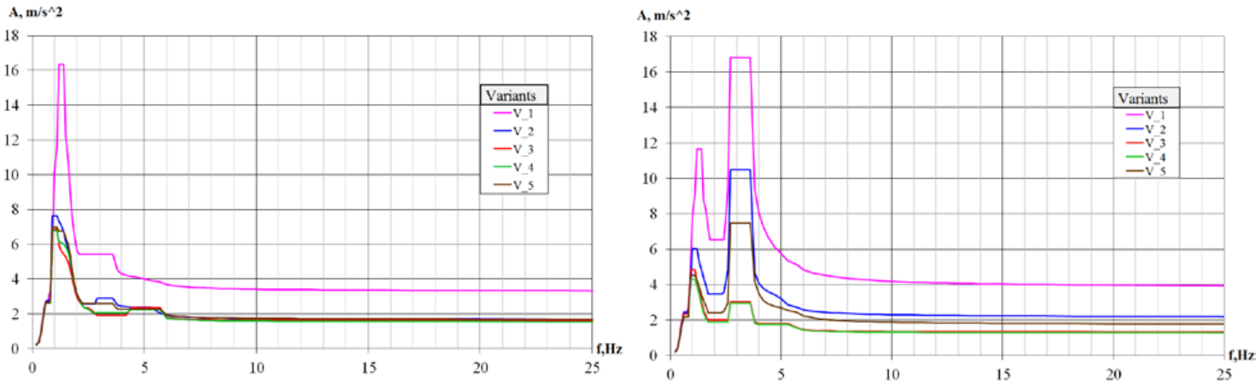


Figure 3. Graphic description of the finite element model of a turbine building developed in the "Nastran" program

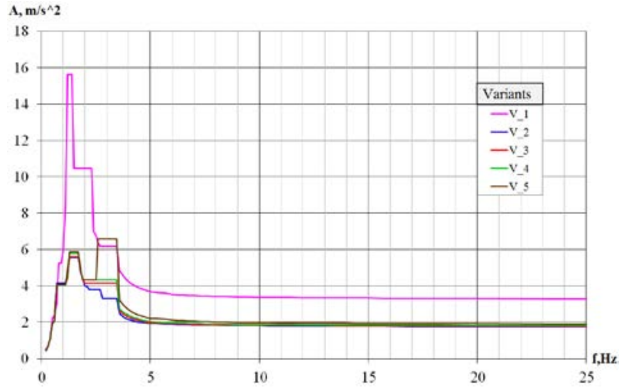
At the final stage of solving the problem, the most effective (preferred) version of the constructive solution was selected to protect the technological equipment as part of the construction object from seismic loads (block 12 of the diagram in Fig. 1) by the highest value of the generalized efficiency indicator (expressions (1) and (2)) calculated according to the following basic principles:

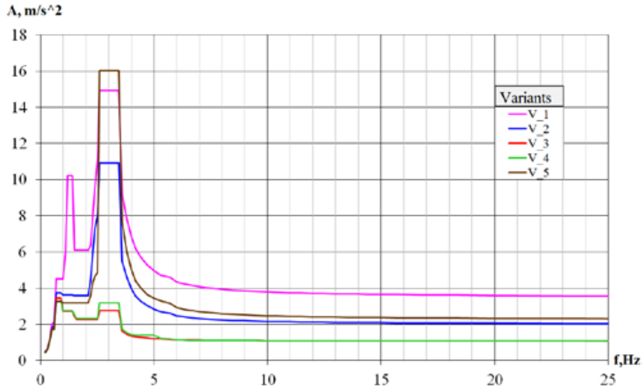
- minimization of peak seismic accelerations at the installation marks of the turbine unit and condensers for axial, transverse and vertical directions;
- minimization of zero-period accelerations at the installation marks of the turbine unit and condensers for axial, transverse and vertical directions;
- minimization of the greatest seismic deformations in insulating elements for axial, transverse and vertical directions.

When performing the appropriate calculations, it was assumed that the above calculated characteristics were equivalent in evaluating the effectiveness of structural solutions, determined by identical values of the corresponding coefficients $\{\alpha_j\}$. In the case of additional critical requirements for seismic accelerations or displacements received from the equipment manufacturer or from technologists, it is possible to vary the coefficients $\{\alpha_j\}$. The results of calculating the values of the generalized performance indicator for alternative options for constructive solutions are presented in Table 4.

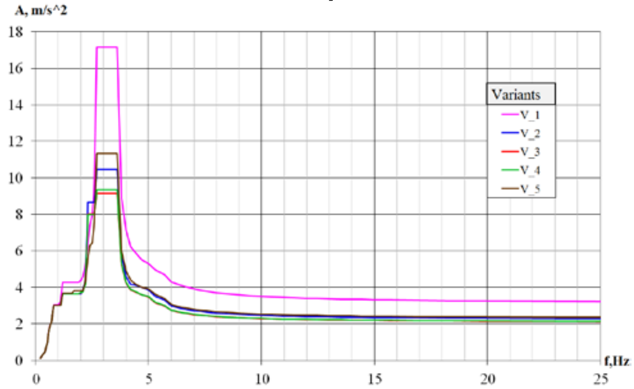


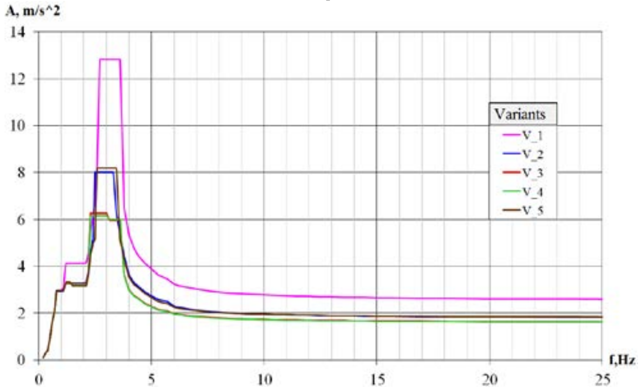
a) d)





b) e)





c) f)

Figure 4. Graphic description of the results of the implementation of simulation experiments in terms of the averaged spectrum of the response of seismic accelerations:
a) at the installation marks of the turbine unit, axial direction;
b) at the installation marks of the turbine unit, transverse direction;
c) at the installation marks of the turbine unit, vertical direction;
d) at the installation marks of the capacitors, axial direction;
e) at the installation marks of the capacitors, transverse direction;
f) at the installation marks of the capacitors, vertical direction.

Based on the results presented in Table 4, it was concluded that option 4 of the design solution for protecting process equipment from seismic effects is most preferred, since the highest value of the generalized efficiency indicator corresponds to this option. The next preferred option is option 3, since the corresponding value of the generalized performance indicator is slightly less than the value of the same indicator for option 4. Moreover, from the point of view of a direct analysis of the results of computational experiments, these options provide a decrease at the installation marks of the capacitors of both peak seismic accelerations and zero period acceleration by more than 2 times, and the extreme values of deformations – by 2-4 times in comparison with the basic version 1 of the design solution. At the same time, at the installation marks of the turbine unit for the indicated design options, the peak seismic accelerations decrease by 4–5 times, the zero period acceleration – by about 3 times, and the largest deformations – by more than 5 times in comparison with the basic version 1.

It is important to note that the results obtained in the framework of the implementation of the proposed procedure on a practical example, in general, correspond to real data for the designs of vibration-insulated foundations of turbine units of power plants with a rigid connection of capacitors to the turbine unit (from the bottom, the capacitors are mounted on spring insulators to compensate for temperature deformations) – relevant examples are high-speed turbine units of the K-1000 and K-1200 models manufactured at the Leningrad Metal Plant (LMP). This circumstance allowed us to conclude that the proposed tool is highly practical.

Based on the comprehensive literature review presented in introduction, we see that there are no publications with methodological recommendations for calculating and designing earthquake-resistant vibroisolated foundations of turbine units.

There are also no articles with numerical results for calculating the vibration-isolated foundations of turbine units.

General conclusions based on the results of seismic calculations are in good agreement with the conclusions obtained in studies on the seismic isolation of buildings and structures of nuclear power plants [3–21].

Table 4. The results of the calculation of the values of the generalized performance indicator for alternatives of constructive solutions.

№ in order	Name of design characteristic	Value for design option (i)					Significance factor
		1	2	3	4	5	
j	-	$q_{i=1,j}$	$q_{i=2,j}$	$q_{i=3,j}$	$q_{i=4,j}$	$q_{i=5,j}$	α_j
1	Normalized peak acceleration at the turbine unit installation marks, axial direction	1	0,47	0,42	0,41	0,43	0,056
2	Normalized peak acceleration at the turbine unit installation marks, transverse direction	1	0,36	0,36	0,37	0,38	0,056
3	Normalized peak acceleration at the turbine unit installation marks, vertical direction	1	0,61	0,53	0,54	0,66	0,056
4	Normalized zero period acceleration at turbine unit installation marks, axial direction	1	0,51	0,49	0,47	0,51	0,056
5	Normalized zero period acceleration at turbine unit installation marks, transverse direction	1	0,54	0,54	0,56	0,58	0,056
6	Normalized zero period acceleration at turbine unit installation marks, vertical direction	1	0,71	0,66	0,66	0,73	0,056
7	Normalized largest value of deformation at the turbine unit installation marks, axial direction	1	0,49	0,3	0,19	0,22	0,056
8	Normalized largest value of deformation at the turbine unit installation marks, transverse direction	1	0,31	0,19	0,12	0,22	0,056
9	Normalized largest value of deformation at the turbine unit installation marks, vertical direction	1	0,33	0,29	0,31	0,39	0,056
10	Normalized peak acceleration at capacitor installation marks, axial direction	1	0,62	0,18	0,18	0,44	0,056
11	Normalized peak acceleration at capacitor installation marks, transverse direction	1	0,35	0,26	0,27	0,31	0,056
12	Normalized peak acceleration at capacitor installation marks, vertical direction	1	0,62	0,49	0,48	0,64	0,056
13	Normalized zero period acceleration at capacitor installation marks, axial direction	1	0,56	0,34	0,33	0,45	0,056
14	Normalized zero period acceleration at capacitor installation marks, transverse direction	1	0,57	0,3	0,3	0,64	0,056
15	Normalized zero period acceleration at capacitor installation marks, vertical direction	1	0,7	0,63	0,63	0,71	0,056
16	Normalized largest strain value at capacitor installation marks, axial direction	1	0,48	0,41	0,39	0,4	0,056
17	Normalized largest strain value at capacitor installation marks, transverse direction	1	0,26	0,23	0,22	0,24	0,056
18	Normalized largest strain value at capacitor installation marks, vertical direction	1	0,32	0,36	0,35	0,43	0,056
	Generalized indicator of the effectiveness of a constructive solution Q_i -	0	0,823	0,977	**0,991**	0,846	

4. Conclusion

As part of the study, the following main results were obtained:

1. The procedure for substantiating the characteristics of structural solutions in the field of protecting vibroisolated foundations of turbine units from seismic influences is proposed;

2. The specified procedure was implemented to solve a practical problem – substantiating the characteristics of the constructive solution of the vibroisolated foundation of the turbine unit. Alternative options are considered, the most preferred option is selected. This option involves the installation of spring insulators of increased stiffness and dampers in the capacitor supports, as well as the installation of spring and spring-damper insulators in the foundation supports of the turbine unit;

3. The certain preferred embodiment of the vibroisolated foundation of the turbine unit allows to reduce seismic acceleration on capacitors by more than 2 times and reduce horizontal seismic movements of capacitors by more than 3 times, compared with existing options.

At further stages of the study, it is planned to improve the developed procedure for calculating and designing earthquake-resistant vibroisolated foundations of turbine units in terms of classifying the corresponding tasks and a more detailed description of the structural features of complex and computational models.

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